A Method for Evaluating Humanoid Robots Using Anthropometric and Biomechanical Data

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Existing Human Factors Guidelines

NASA Constellation Program Human-Systems Integration Requirements (CxP-HSIR)

- Uses human metrics to drive spacecraft design
- Defines requirements for radiation, safety, waste management, **anthropometry, range of motion, mass properties, and strength**
- Gives us a way to reverse engineer how to evaluate a robot that will operate well on a spacecraft.

NASA Human Integration Design Handbook (HIDH)

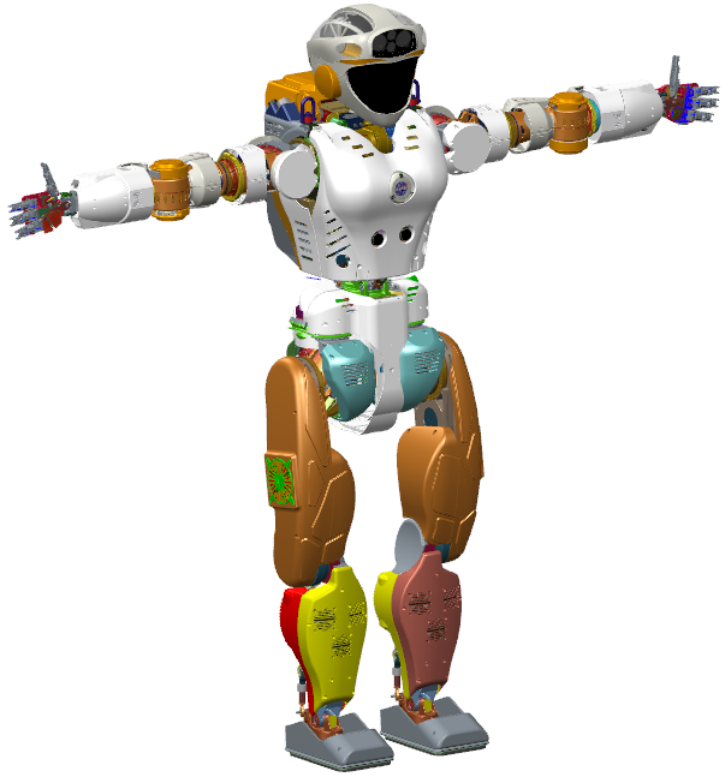
- Cites CxP-HSIR and provides criticality levels for strength metrics

Criticality Definitions

- Criticality 1: Requirement for activity related to crew safety.
- Criticality 2: Requirement for activity related to loss of mission.

Anthropometry

- **Measurement**: Body Sizes & Proportions
- **Rationale**
  - Fit through passageways
  - Reach controls, displays, & equipment
- **Human data**
  - 59 CxP-HSIR measurements
- **Valkyrie data**
  - Robot model
  - Physical measurements
- Passes 35 of 59 (**59%**) measurements



Range of Motion

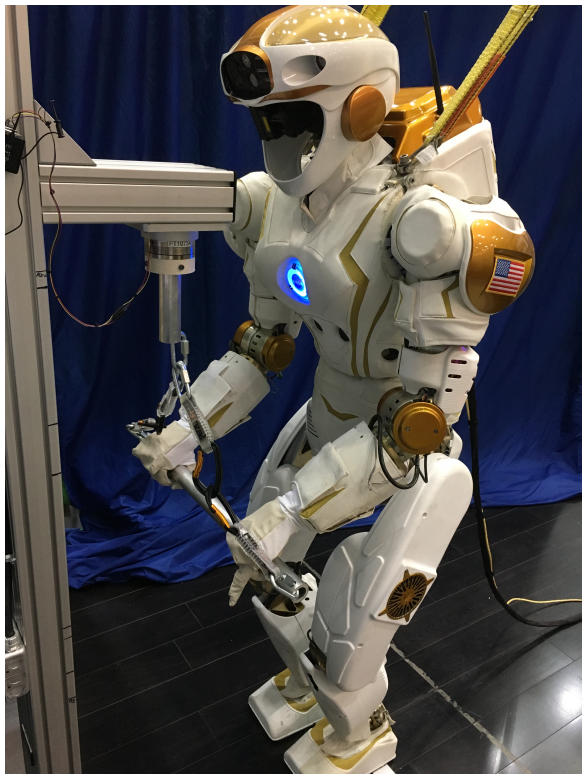
- **Measurement**: Joint Degrees of Freedom
- **Rationale**
  - Interact with controls, tools, & equipment
  - Sufficient reach mobility
- **Human data**
  - 25 CxP-HSIR movements
- **Valkyrie data**
  - Joint limits in robot model
- Passes 16 of 25 (**64%**) movements

Body Mass

- **Measurement**: Whole-Body and Body-Segment Masses
- **Rationale**
  - Weight rating for seats, brackets, & restraints
  - Likelihood of damaging equipment
- **Human data**
  - 12 body-segment, 3 combined body-segment, & 1 whole-body CxP-HSIR mass
- **Valkyrie data**
  - Center of mass table measurements
- Passes 2 of 16 (**13%**) masses

Strength

- **Measurement**: Movement Force Output
- **Rationale**
  - Operating force for controls, tools, & equipment
- **Human data**
  - 34 CxP-HSIR movements
- **Valkyrie data**
  - 6-axis load cell, base, & handle attachments
- Passes 12 of 34 (**35%**) crit. 1 forces
- Passes 11 of 34 (**32%**) crit. 2 forces
- Passes 5 of 34 (**15%**) normal operating forces



Questions?